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STUDY PLAN

HYDROLOGIC IMPACTS
OF
HARVESTING
PINE

by S. J. Ursic
1975

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INTRODUCTION

After decades of exploitative row-crop agriculture and severe erosion, millions of acres of the hilly southern Coastal Plain were abandoned. Unprotected, these lands were further decimated by erosion, while runoff and sediment caused serious downstream damage. Aided by the advent of fire control, large areas developed vegetal cover and gradually reverted to forest, thus tending to stabilize the soil. But a widespread need to accelerate protection stimulated massive tree-planting programs. The intensive effort to rehabilitate eroding lands is exemplified on the 4.2-million-acre Yazoo Basin in north Mississippi, where in 25 years approximately 1 acre of every 7 has been planted or converted to loblolly pine, primarily for watershed improvement.

Even more intensive planting programs are not unusual. In Tennessee, pine has been planted on 20,000 acres of eroded and abandoned lands on the Natchez Trace State Forest--a 42,000-acre tract near Lexington and a similar proportion of the Chickasaw State Forest in the adjoining county. These examples testify to the severity of previous erosion and to the fact that much of the southern pine forest land base consists of severely eroded, fragile soils.

Previous research by the Tennessee Valley Authority on Pine Tree Branch Watershed, also near Lexington, Tennessee, and at the Forest Hydrology Laboratory at Oxford, Mississippi, has demonstrated loblolly pine the ideal erosion-control plant. On small upland

catchments, sediment production was reduced to near pristine levels in less than 20 years and dramatic decreases were demonstrated on the larger (88-acre) Pine Tree Watershed despite continuing outflow of sediment from sand channels. In addition, peak flows and, on most soils, storm runoffs were reduced.

Pine planted to stabilize eroding lands now represents a tremendous resource. Many plantations established in the 1930's are sawlog size and each year a large acreage of plantations established after World War II reaches pulpwood rotation age.

Clearcutting after a pulpwood rotation is a standard accepted practice for the southern pines with or without intermediate cuttings. The greatest demand in the South is for small roundwood products (pulp, plywood, posts, poles). Clearcutting reduces management and harvesting costs and forest managers are becoming increasingly reluctant to rely on silvicultural systems to obtain natural regeneration. Development of superior stock also dictates clearcutting and planting. Despite its advantages, however, clearcutting maximizes site disturbance and the tolerance of eroded lands to disturbance after the initial rotation of pine is unknown.

Society is demanding that a reduction in costs to provide one forest commodity will not increase the costs of providing or restoring another basic forest land resource. This concern has resulted in Public Law 92-500 administered by the Environmental Protection Agency.

Currently, non-point pollution from forests is receiving much attention. The threat of concern for forest management practices is, of course, changes in water quality and quantity. There is also--especially for the more severely eroded lands--the threat of negating the environmental benefits derived from the plantations and another round of costly rehabilitation.

Since all plantations will not be planted after clearcutting or final harvest, and this problem may be especially acute for small private holdings, the need to obtain adequate pine stocking through natural regeneration with techniques compatible with protecting the soil and water resource must be considered. Thus, before clearcutting erosion-control plantations is widely adopted or recommended for erosive sites, research is needed to hydrologically evaluate clearcutting and alternative silvicultural systems suitable for the even-aged management of loblolly pine.

This study is designed to determine the hydrologic changes following clearcutting loblolly pine planted on abandoned agricultural lands. Treatments will include the use of temporary minor vegetation following clearcutting and a natural regeneration system. Emphasis in this plan is on the amount and distribution of storm runoff and sediment production. A separate work plan will be prepared for a companion study, which will look at changes in chemical water quality--primarily N-P-K constituents--both in solution and as attached to organic and inorganic particulate matter.

COOPERATION

The principal cooperators who have made this study possible are Mr. James R. Crouch, Project Manager of the Yazoo-Little Tallahatchie Flood Prevention Project, State and Private Forestry, U.S. Forest Service, Oxford, Mississippi; Mr. Max J. Young, State Forester of Tennessee, Division of Forestry, Tennessee Department of Conservation, Nashville, Tennessee; and Dr. Thomas H. Ripley, Director, Division of Forestry, Fisheries and Wildlife Development, Tennessee Valley Authority, Norris, Tennessee.

The Yazoo-Little Tallahatchie Project took an active part in deciding on study treatments to help guide future management of some 650,000 acres of loblolly plantations in the Yazoo Basin and provided financial and other assistance.

The Tennessee State Forester's Office is providing lands for one study location, assistance in tree planting, and cooperation in numerous phases of the work through District personnel at Lexington, Tennessee, and the Park Ranger at the Natchez Trace State Forest.

The Tennessee Valley Authority is providing land, tree planting, and other cooperation and assistance through their personnel at Norris, Tennessee; Muscle Shoals, Alabama; and at the field office at Lexington.

OBJECTIVES

The main objective is to determine the hydrologic effects and their duration--primarily storm runoff and sediment production--of harvesting erosion-control loblolly plantations.

A second, longer term but equally important objective is to develop the capability to predict and extrapolate results over a wide range of conditions within the soil-physiographic area represented. This will require measurements and observations to characterize the catchments, the disturbances due to logging, and the changes resulting from removing the pine cover. Included, in addition to topographic and climatic data, will be initial impacts on soil properties, the forest floor, and minor vegetation, and changes of these variables with time.

SCOPE

Soils are a key consideration in defining the scope of this study. The principal soils involved are among the most erosive in the Coastal Plain. They were developed from shallow loess of Pliocene age deposited over mostly sandy Coastal Plain materials of Cretaceous age. The loessial soils are representative of a large acreage contiguous to the Mississippi Alluvial Plain from Cairo, Illinois, to the Gulf and extending eastward 50 or more miles. The Coastal Plain soils represented are important and widespread forest soils in all the states of the South and Atlantic Coastal Plain from Texas to Virginia.

Another important consideration in defining the scope of the study is the logging method. Trees were felled, limbed and then skidded tree-length to landings with rubber-tired equipment--the most prevalent method of moving stems from stump to loading point in the South at this time. Logging was supervised and obvious malpractices such as skidding within drainages and gullies were avoided. The general practice was to fell trees on contour, skid them on contour to the closest ridge, and to follow the ridgeline to a landing on or near a truck road. In short--generally recommended, common-sense practices were followed. This is worth stressing since far different treatment responses could be expected from "skidders' choice."

The size of the catchments involved largely negate any channel effects on treatment response. However, the fortune of having catchments within Pine Tree Branch watershed will provide invaluable information on the effects of watershed size, especially on water quality.

LOCATION AND DESCRIPTION

The study is located near Lexington, Tennessee, which is about 20 miles east of Jackson, Tennessee. Two replications (8 catchments) are on the Natchez Trace State Forest, hereafter the "Trace", and two replications are on TVA's gaged 88-acre Pine Tree Branch Watershed, hereafter "Pine Tree" (figure 1).

Seven of the catchments on the Trace are along Brown's Creek Lake Road and one is at the junction of this road and the Natchez Trace Road. Locations and treatments are shown in figure 2. Catchment locations and treatments on Pine Tree are shown in figure 3.

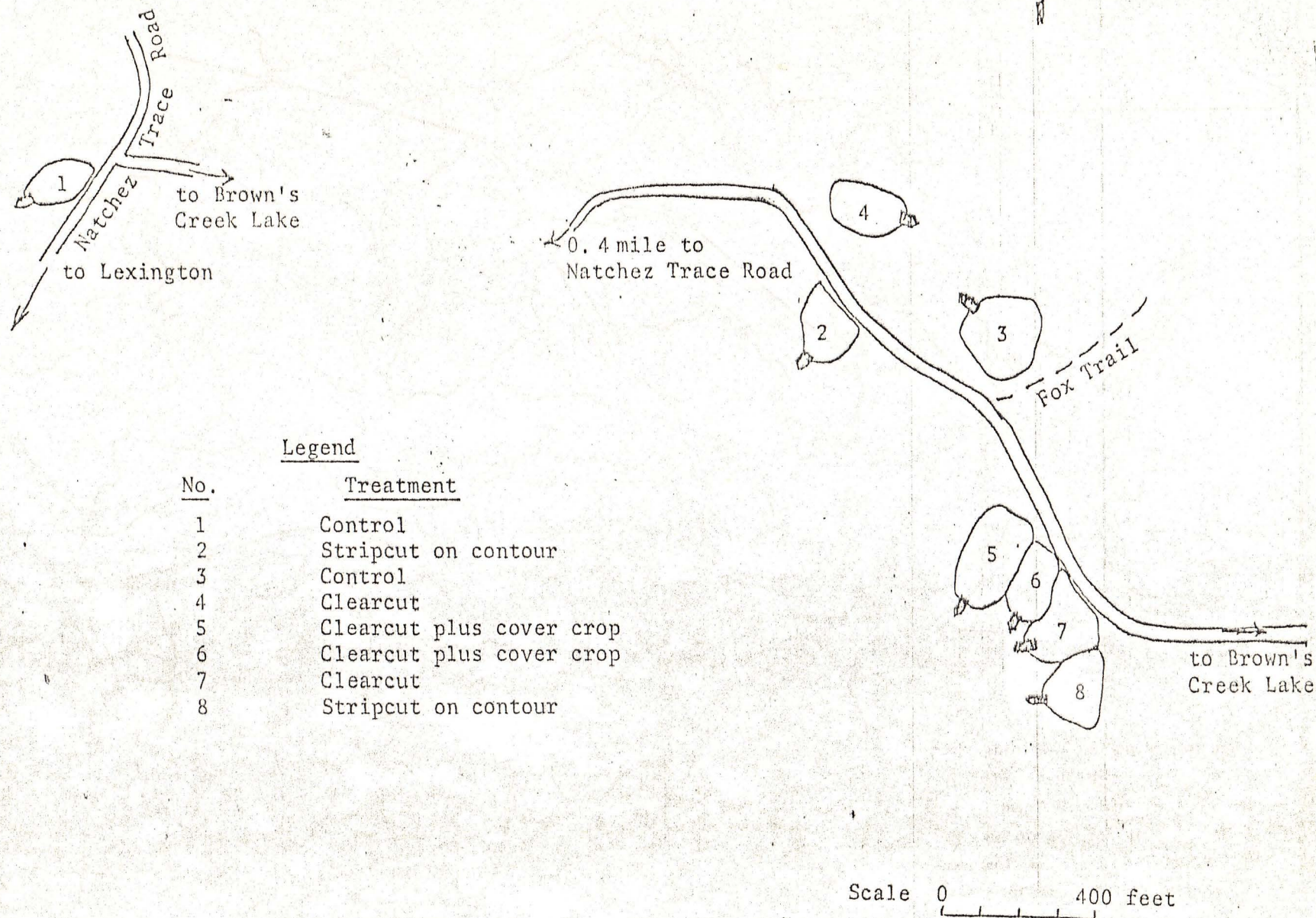


Figure 2.--Location of study catchments on Natchez Trace State Forest.

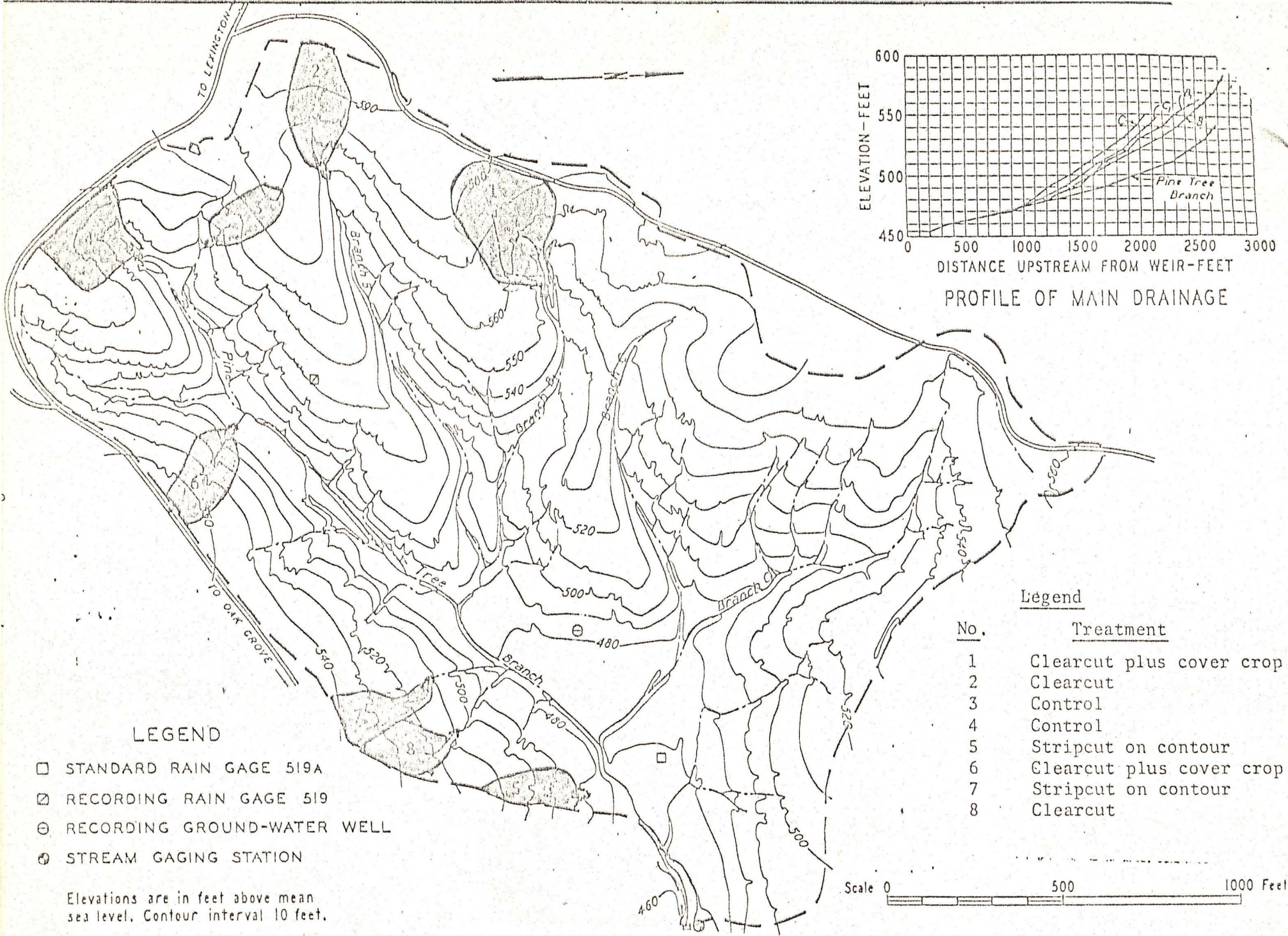


Figure 3.--Location of study catchments on Pine Tree Branch.

The two locations are about 4.5 miles apart. All catchments, except one on the Trace, are within the Beech River drainage. All are underlain by the McNairy sand member of the Ripley formation.

Soils on Pine Tree are mapped as Providence silt loam (loess) on the ridge tops and upper slopes grading into Ruston sandy loam on the steeper mid to lower slopes. The Providence series is a loess soil with a fragipan.

Soils on the Trace are similar except, on the more generalized county soil map, the loess is mapped as Lexington--a silt loam without a fragipan. The distinction between loess soils at the two areas--with and without the fragipan which is known to perch water and increase stormflows during the wet, dormant season--is considered a variable in the analysis of variance. However, before this analysis is accepted, soils on the catchments will be mapped in detail to determine if they truly represent two different populations.

The loblolly on the Trace catchments were planted in 1938; those on Pine Tree in 1946. The discrepancy in age is not thought to be a problem since all catchments, at the time of the severe January 1974 ice storm, were well stocked and had a deep, continuous forest floor--the most important cover variable influencing overland flow and sediment production. Plantations on the study catchments have been thinned but skidding was with horses and no lasting effects were noted at either location.

The climate of west Tennessee is humid with mild winters and hot summers. The growing season lasts about 200 days. Annual rainfall averages 50 inches with late winter and early spring the wettest months.

A wealth of information on Pine Tree is found in TVA's publication, "Reforestation and erosion control influences upon the hydrology of the Pine Tree Branch watershed, 1941 to 1960,"^{1/} much of it applicable to the Trace as well.

METHODS

Treatments

The study includes the following treatments:

1. Clearcut -- A commercial pulpwood clearcut. Haul roads and landings will be excluded due to the small size of the catchments. Recommended skidding practices followed. Loblolly seedlings planted at a 7- x 7-foot spacing.

2. Clearcut plus cover crop -- Treatment as in 1, plus sowing and fertilizing disturbed areas of bare soil with a winter grass at rates recommended by Natchez Trace State Forest Wildlife Management personnel. Loblolly seedlings planted at a 7- x 7-foot spacing.

An option for this treatment will be to reseed and refertilize a cover crop on the entire catchment in the fall of 1975--about one year after cutting. The need for this will be determined by the extent of oxidation of the forest floor and invasion by minor vegetation.

^{1/} Tennessee Valley Authority. 1962. Reforestation and erosion control influences upon the hydrology of the Pine Tree Branch watershed, 1941 to 1960. Div. Water Control Planning and Div. For. Development, Knoxville, Tenn. 98 p.

3. Stripcut on contour -- Seed trees left on undisturbed filter strips running on contour. Width of undisturbed leave strips will be a function of stand density. They will be adjusted to leave 20 to 25 square feet of basal area per acre and at least 15 feet wide to permit subsequent removal of seed trees efficiently and without damage to the regeneration or further disturbance to the previously logged segments of the catchments. Cut 1-chain-wide strips on contour. Trees felled and skidded on contour. The first leave strip will start at the flume site.

4. Control -- No cutting or other disturbance.

All residual stems (pine and hardwood) over one-half inch dbh on the logged areas will be cut or injected with herbicide after logging.

To avoid confounding effects, honeysuckle and kudzu on the logged catchments will be controlled with herbicide. Control catchments will not be sprayed because of probable negligible effects of the vines on hydrologic performance.

The size of the catchments sought was 1 acre. Final drainage areas will probably range between 0.75 and 2 acres.

Design and Analysis

The design is a completely randomized factorial. One factor is soil and will have two levels--the Providence-Ruston association on Pine Tree Branch and Lexington-Ruston on Natchez Trace State Forest. The other factor is treatment--the four levels already described. Each treatment will be repeated twice on each soil for a total of 16 catchments.

The assumed model is:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_1X_2 + B_6X_1X_3 + B_7X_1X_4 + E$$

where Y = primarily stormflow volumes, peak flows, and sediment yields/storm, but can also include average sediment concentrations, water quality constituents, etc. Emphasis is on individual events but quarterly or annual data are also of interest.

$X_1 = 1$ when location is Pine Tree

$X_1 = 0$ when on the Trace

$X_2 = 1$ if clearcut applied

$X_2 = 0$ if not clearcut

$X_3 = 1$ if treatment clearcut plus cover crop applied

$X_3 = 0$ if not clearcut plus cover crop

$X_4 = 1$ if stripcut treatment applied

$X_4 = 0$ if not stripcut

The analysis of variance table for this design will be:

<u>Source of variance</u>	<u>df</u>
Soil	1
Treatment	3
Soil x treatment	3
Error	8
Total	15

The three degrees of freedom associated with treatment will be used in an orthogonal set of single df comparisons:

<u>Comparison</u>	<u>Treatment</u>			<u>Clearcut + cover crop</u>
	<u>Control</u>	<u>Stripcut</u>	<u>Clearcut</u>	
1 Uncut vs cut	3	-1	-1	-1
2 Clearcut vs clearcut + cover crop	0	0	+1	-1
3 Stripcut vs clearcut	0	+2	-1	-1

It must be noted that complete randomization was not possible. First, the study was opportunistic and feasible only because of the January 1974 ice storm.

Damage on Pine Tree was so severe that the decision was made to clearcut the entire watershed with the exception of green strips along the main gully channels. Here, all possible catchments were considered and the best eight selected. On the much larger Trace, the eight catchments had to be clustered to minimize rainfall variability. In addition, all catchments had to have reasonable size and conformation, an inactive channel, no problems with roadwater, a dominantly pine cover, and a suitable flume site.

Treatment assignment was to some extent determined by the amount and pattern of ice damage. The controls had to be among the catchments subjected to lighter ice damage. Another restriction was not to place a stripcut next to a control because of the unwanted extra seed source. Thus, when necessary, controls were identified and, insofar as possible, treatments assigned at random to the remaining catchments.

The net effect of all this is that a possible bias may have been introduced. The clearcuts generally were more severely ice damaged and, if it is determined that they also experienced a higher proportion of uprooting, this could indicate shallower and more severely eroded soils. Thus, differences in stormflows and perhaps sediment production resulting from clearfelling might be greater than if treatments had been assigned completely at random.

The positive side is that hydrologic parameters following clearcutting may also be compared with proposed standards (ppm, etc.). Thus, if clearcutting does prove environmentally acceptable and a bias does exist, the evidence for acceptability will be stronger as a result of clearcutting the more severely eroded areas. Detailed soil mapping and sampling of the catchments needed to develop predictive models will help clarify the problem of bias.

It is also possible that harvesting the larger trees on the Trace will cause more soil compaction than on Pine Tree, but this effect will be at least partially offset by fewer runs with the skidder.

Instrumentation

Stormflows will be measured in pre-calibrated H-type flumes equipped with FW-1 water-stage recorders using 12-hour time gears. The flumes will be anchored to small concrete drop-box approach sections. Controls and stripcuts will have 1-foot H-flumes (capacity 2 cfs), and the clearcut treatments 1.5-foot H-flumes (capacity 5.4 cfs).

Samples for sediment production and water quality analyses will be obtained with slotted wheel-type samplers designed and built as an integral part of the flumes. The N-1 wheel used with the 1-foot flume extracts a sample proportional to flow rate equivalent to 0.5 percent of total flow; the N-3 wheel used with the 1.5-foot flume collects 0.33 percent. Stormflows sampled by the wheels are routed through a 2-percent sampler developed at the Forest Hydrology Laboratory and

collected and stored in 2.5- and 5-gallon plastic cans. A 5-gallon can will handle the sample from a stormflow of 1.84 acre inches from catchments instrumented with 1-foot flumes and 2.79 acre inches from those with 1.5-foot flumes.

Probable maximum instantaneous peak flows were calculated from the Rational runoff formula:

$$Q = CIA$$

Where: Q is discharge in cfs

C is the runoff coefficient

I is the rainfall intensity for the time of concentration (t_c)

A is the catchment area in acres

Assuming a t_c of 5 minutes and a return period of 50 years, $I = 8.4$ inches per hour and assuming $C = 0.25$ for stripcut areas and 0.6 for clearcuts, maximum expected peak flows are:

	<u>Estimated peak flows--cfs</u>	<u>Flume capacity</u>
Stripcut	2.1	2.0
Clearcut	5.0	5.4

Rainfall will be measured with automatic punch-type recorders supplemented with a minimum of two standard raingages (Forest Service type) at each study location.

Plans, details, and other pertinent information on construction and installation will be included in the Establishment Report.

Soil-Vegetation Surveys

Assistance will be sought from the Soil Conservation Service through their office at Lexington to more closely map and verify the soil series and types represented on the Trace catchments. Soils on Pine Tree have been mapped in more detail, but checks on soil boundaries and nomenclature will be desirable. Mr. Aaron Peters with the Soil Conservation Service at Lexington has expressed an interest in this study and will probably work with us on this phase of the study.

An initial survey will determine the extent and type of logging disturbance and the components of ground cover including the supplemental cover crop. This will be done from point measurements on random, permanent line transects. The depth and weight of the forest floor and the depth and organic matter content of the A_1 horizon will be determined from 0.96 ft.² samples taken at random distances along the transects. Remeasurements and additional sampling from the permanent transects will be made at least annually to define ground-cover trends and the restoration of the forest floor on the clearcut-and-plant treatments. Invasion of hardwoods and volunteer minor vegetation will be determined from counts and ground-line clipping on larger (9.6 ft.²) plots and, natural pine regeneration, on milacre plots. A complete inventory of the pine will be made on the controls and stripcuts.

Since prelogging estimates of the forest floor and other soil-cover variables were not obtained, appropriate comparisons will be with estimates obtained by sampling the control watersheds.

Details of the soil, vegetation, and ground-cover surveys and a summary of initial conditions after logging will be included in the Establishment Report.

PRESENTATION OF RESULTS

Details of installation including maps of soils and catchment boundaries, deviations from the Study Plan, a chronology, costs, pertinent observations, and, as appropriate, measurement data, will be recorded in file memoranda as completed and presented in an Establishment Report.

A progress report covering operations during 1975 will be prepared early in 1976 and, at least, annually thereafter.

Reports will be furnished to all cooperators and will include recommendations for publication of study findings.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
SOUTHERN FOREST EXPERIMENT STATION

P. O. BOX 947

OXFORD, MISSISSIPPI 38655

1630

April 25, 1975



Mr. Richard Klason
Division of Forest Resources
North Carolina Department of Natural
& Economic Resources
Post Office Box 27687
Raleigh, North Carolina 27611

Dear Dick:

I wish I could answer the questions in your April 9 letter, but they are essentially those posed for the research we are just starting.

Without actually measuring stormflows and sediment yields and, preferably, those delivered to a channel, the best I think one can do is resort to empirical formulae such as the modified Musgrave's or the Universal Soil Loss Equation (Wischmeier). However, if permanent plots, transects, cross-sections, etc., are used to characterize disturbances and recovery trends, the information, although relative, could be quite valuable. The initial impact of alternative practices could also be compared. Perhaps such work could be done as part of the cooperative study with Jim Douglass.

Our harvesting study in Tennessee is now fully operative. I am sending you a copy of the study plan as previously promised; also, a recent paper which may be of interest. We are also going to measure runoff and sediment production from unreplicated 5-acre catchments. Treatments will include bedding steep lands on contour and double-chopping.

Sorry I can't be more constructive.

Best wishes.

Sincerely,


S. J. URSIC
Project Leader

Enclosures (1602-75-1; "Pine mgmt influences...")

cc: Mr. J. L. Stewart
Dr. L. E. Douglass